PROTON STABILITY IN 5D GUTS WITH ORBIFOLD COMPACTIFICATION

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We construct SU(5) SUSY GUT in 5D compactified on S^1/Z_2 orbifold where the matter fields are living in the five dimensional bulk. SU(5) symmetry is broken down to the Standard Model gauge group by the orbifold projection which automatically ensures stability of proton in all orders of perturbation theory. The model predicts extra mirror quark-lepton families which along with the GUT particles and the excitations of extra dimensions could be observable at high energy colliders providing the unification scale is in the TeV range.

Recently, various issues of four dimensional (4D) particle phenomenology have been reconsidered within the higher dimensional theories. The models with large extra dimensions are particularly interesting from phenomenological and experimental point of view [1,2]. Typically such models suffer from the potentially large and thus phenomenologically unacceptable violation of certain global symmetries. A large flavour changing neutral currents, large neutrino masses, unacceptably fast proton decay etc. could be indueced in the low-energy effective theory. In this note we will concentrate on the proton stability problem in higher dimensional GUTs with low scale unification [3].

Let us consider supersymmetric $SU(5)$ model in higher-dimensional space-time. For simplicity we restrict our discussion by the case of one compact extra space-like dimension. As usually, each family of ordinary quarks and leptons is placed in $\overline{5}$ and 10 irreducible representations of the $SU(5)$ group but now the ordinary quarks and leptons are supplemented by the mirror states. The mirror states combine with ordinary quarks and leptons to form $N=2$ hypermultiplets: $\mathcal{Q}=(Q_L,Q_R)\sim\overline{5}$, $\mathcal{D}=(D_L,D_R)\sim 10$. Here $Q_L(D_L)$ and $Q_R(D_R)$ are $N=1$ left-handed and right-handed chiral quintuplet (decuplet) superfields, respectively. $N=2$ $SU(5)$ vector supermultiplet $\mathcal{V}=(V,\Phi)$ contains $N=1$ 4-dimensional gauge superfield $V=\left(A^{\mu},\lambda^1,X^3\right)$ as well as $N=1$ chiral superfield $\Phi=\left(\Sigma+iA^5,\lambda^2,X^1+iX^2\right)$ both in the adjoint representation of the $SU(5)$ group. Finally, we also need to introduce at least one $SU(5)$ fundamental and one anti-fundamental hypermultiplets: $\mathcal{H}=(H_L,H_R)\sim 5$, $\widetilde{\mathcal{H}}=(\widetilde{H}_L,\widetilde{H}_R)\sim\overline{5}$, where the electroweak Higgs doublet

Fields		Z_2 parity, $\mathcal{P}$
Vector supermultiplet, $\mathcal{V}$	$G(\Phi_G) \sim (8,1,0)$	$+(-)$
	$W(\Phi_W) \sim (1,3,0)$	$+(-)$
	$S(\Phi_S) \sim (1,1,0)$	$+(-)$
	$X,(\Phi_X) \sim \left(\overline{3},2,-\sqrt{\frac{5}{12}}\right)$	$-(+)$
	$\overline{X}(\Phi_{\overline{X}}) \sim \left(3,2,\sqrt{\frac{5}{12}}\right)$	$-(+)$
Quintuplets, $\mathcal{Q}$, $\widetilde{\mathcal{Q}}$	$\overline{d}_{L(R)}, \widetilde{\overline{d}}_{L(R)} \sim \left(\overline{3},1,-\sqrt{\frac{2}{15}}\right)$	$-(+), +(-)$
	$l_{L(R)}, \widetilde{l}_{L(R)} \sim \left(1,\overline{2},\sqrt{\frac{3}{20}}\right)$	$+(-), -(+)$
Decuplets, $\mathcal{D}$, $\widetilde{\mathcal{D}}$	$\overline{u}_{L(R)}, \widetilde{\overline{u}}_{L(R)} \sim \left(\overline{3},1,\frac{2}{\sqrt{15}}\right)$	$-(+), +(-)$
	$q_{L(R)}, \widetilde{q}_{L(R)} \sim \left(3,2,-\frac{1}{\sqrt{60}}\right)$	$+(-), -(+)$
	$\overline{e}_{L(R)}, \widetilde{\overline{e}}_{L(R)} \sim \left(1,1,-\frac{3}{\sqrt{15}}\right)$	$-(+), +(-)$
Higgs hypermultiplets, $\mathcal{H}, \widetilde{\mathcal{H}}$	$h^C_{L(R)} \sim \left(3,1,\sqrt{\frac{2}{15}}\right)$	$-(+)$
	$h^W_{L(R)} \sim \left(1,2,-\sqrt{\frac{3}{20}}\right)$	$+(-)$
	$\widetilde{h}^W_{L(R)} \sim \left(1,2,\sqrt{\frac{3}{20}}\right)$	$+(-)$
	$\widetilde{h}^C_{L(R)} \sim \left(\overline{3},1,-\sqrt{\frac{2}{15}}\right)$	$-(+)$

Table 1. Z_2-parities $\mathcal{P}$ of various fields.

(anti-doublet) $h^W_{L(R)}$ ($\widetilde{h}^W_{L(R)}$) presumably resides. One obvious advantage of the $N=2$ supersymmetric GUTs is that the gauge fields in V and scalars in Φ are unified in the same $N=2$ vector supermultiplet $\mathcal{V}$. The scalar component of the chiral superfield Φ can be used to break $SU(5)$ gauge symmetry. Alternatively, one can break $SU(5)$ invariance through the orbifold compactification. We consider here the later possibility by compactifying the extra fifth dimension on an S^1/Z_2 orbifold [2,4]. What we will require additionally is the conservation of B and/or L global charges upon the compactification. In fact this can be achieved rather naturally. First, in addition to the particle content given above, we have to introduce an extra quintuplet $\widetilde{\mathcal{Q}} \sim \overline{5}$and an extra decuplet $\widetilde{\mathcal{D}}, \sim 10$ of matter fields per each family of quarks and leptons. The second step is to appropriately project the different states in $\mathcal{Q}$, $\widetilde{\mathcal{Q}}$, $\mathcal{D}$, and $\widetilde{\mathcal{D}}$ upon the dimensional reduction. This can be done by assigning different orbifold Z_2-numbers to the quarks and leptons (and their mirrors) in $\mathcal{Q}$, $\widetilde{\mathcal{Q}}$, $\mathcal{D}$, and $\widetilde{\mathcal{D}}$ as it is given in Table 1. According to the Fourier expansion of 5D fields, the wave functions of the parity-odd fields vanish at the orbifold fixed-points ($y = 0, \pi$) and only parity-even fields can propagate on the 4-dimensional boundary walls. This suggest the identification of ordinary quarks and leptons with $\mathcal{Q}$,$\widetilde{\mathcal{Q}}$, $\mathcal{D}$ $\widetilde{\mathcal{D}}$ fragments as: $\widetilde{\overline{d}}_L, \widetilde{\overline{u}}_L, q_L, l_L, \widetilde{\overline{e}}_L$. There also present their mirror states on the boundary wall: $\overline{d}_R, \overline{u}_R, \widetilde{q}_R, \widetilde{l}_R, \overline{e}_R$. The gauge symmetry on the fixed point $y = 0$ is just $SU(3)_C \otimes SU(2)_W \otimes U(1)_Y$ one and $N = 2$ supersymmetry is reduced to the $N = 1$. Beside the mirror states we have some additional states beyond the usual particle content of the MSSM as one can see from Table 1.

Now, since the gauge superfields $X, \overline{X}$ are Z_2-odd, they decoupled from the zero modes of quarks and leptons and thus they can not be responsible for the B and L violating interactions among them anymore. The adjoint scalar superfields Φ_X and $\Phi_{\overline{X}}$, contrary, have a zero modes and couple to the matter on the boundary wall. However, they can only transform the mirror quarks into the ordinary leptons and the mirror leptons into the ordinary quarks. So among the possible final states along with the ordinary quarks and leptons always will appear the mirror ones. This actually means that in the limit of massless ordinary quarks and leptons and their mirror partners the following global charges are separately conserved: $Q_1 = B + L_M, Q_2 = L + B_M$, where the mirror baryon and lepton numbers we denote as B_M and L_M, respectively. To generate the masses for the ordinary quarks and leptons and their mirror partners we add $N = 2$ supersymmetry violating Yukawa terms on the boundary wall at $y = 0$ [3]. These Yukawa terms contain only zero modes of the fields and thus the colored Higgs triplets from H_L and $\widetilde{H}_L$ completely decoupled from the quarks and leptons as well as from their mirror partners. This is intrinsically geometric mechanism for the doublet-triplet splitting. Thus, the Yukawa interactions on the boundary wall respect the global charges Q_1 and Q_2. It is evident now that, since the mirror particles is assumed to be heavier than the ordinary ones, the proton decay is forbidden kinematically. In other words, as long as mirror particles cannot be produced B and L are separately conserved. As a result the proton is absolutely stable in all orders of perturbation theory.

References

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